Performing and interpreting a lumbar puncture

Lumbar puncture for CSF sampling is a commonly used investigation and diagnostic tool in medicine. Lumbar puncture has an important role in the diagnosis of several pathologies including CNS infection and subarachnoid haemorrhage and can be used to administer medication.

There are risks associated with lumbar puncture, so knowledge of the indications, contraindications, anatomy and practical skills for performing a lumbar puncture is important. This article outlines the principles of performing a lumbar puncture, tips for optimizing success and gives a guide to interpreting the results.

Indications

Urgent indications for lumbar puncture include:

- Diagnosis of bacterial, viral and fungal CNS infections
- Diagnosis of subarachnoid haemorrhage in patients of high clinical suspicion, but with negative computed tomography of the head (up to 4% of aneurysmal subarachnoid haemorrhages will be missed on computed tomography) (Mark et al, 2016).

Non-urgent indications for a lumbar puncture include:

- Investigation of CNS inflammatory disease, e.g. multiple sclerosis
- Diagnosis and treatment of idiopathic intracranial hypertension.

Other indications:

- Lumbar puncture is used for the administration of medications into the CSF, e.g. spinal anaesthesia, chemotherapy.

CSF culture is the gold standard in the diagnosis of bacterial meningitis. If meningitis is suspected, blood tests and neuroimaging should not take priority over lumbar puncture unless the patient has a bleeding disorder or there are clinical signs suggesting raised intracranial pressure, e.g. focal neurological signs or reduced Glasgow Coma Scale (McGill et al, 2016).

Contraindications

Contraindications to lumbar puncture include:

- Raised intracranial pressure – lumbar puncture in these patients can lead to brainstem herniation
- Bleeding disorders (see below)
- Patients on anticoagulant and/or antiplatelet drugs (see below)
- Infection of the skin overlying the site of insertion.

Coagulopathy increases the risk of spinal haematoma and subsequent nerve injury after lumbar puncture (Vandermeulen et al, 1994). *Table 1* summarizes the indications and contraindications for lumbar puncture.

Antiplatelets and anticoagulants

Aspirin therapy is not a contraindication to lumbar puncture, and does not need to be withheld or stopped. If a patient is taking other antiplatelet or anticoagulant medications, e.g. low molecular weight heparin or clopidogrel, these should be stopped before a lumbar puncture is performed. Both the Association of Anaesthetists of Great Britain and Ireland and the Association of British Neurologists, have produced guidelines outlining the 'safe window' for performing a lumbar puncture before and after administration of different

Table 1. Indications and contraindications for lumbar puncture

Indications	Investigation and diagnosis of:	■ CNS infection (meningitis, encephalitis) ■ Subarachnoid haemorrhage ■ Multiple sclerosis ■ CNS lymphoma ■ Idiopathic intracranial hypertension ■ Guillain–Barré syndrome
	Administration of:	■ Spinal anaesthesia ■ Intrathecal chemotherapy ■ Intrathecal antibiotics
Contraindications	Coagulopathy	■ Thrombocytopaenia with platelet count <50 x 10^9/litre ■ International normalized ratio >1.5 ■ Low molecular weight heparin treatment dose <12 hours before lumbar puncture ■ Low molecular weight heparin prophylactic dose <24 hours before lumbar puncture ■ Oral anticoagulant use*
	Raised intracranial pressure	
	Infection over insertion site	
	Patient refusal	

**safe timeframes for performing lumbar puncture after stopping oral anticoagulants are outlined by Association of Anaesthetists of Great Britain and Ireland (Harrop-Griffiths et al, 2013)*

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antiplatelet and anticoagulant medications (Harrop-Griffiths et al, 2013; Dodd et al, 2018).

Bleeding disorders

van Veen et al (2010) suggest that a platelet count of 40 x 10^9/litre is safe for performing a lumbar puncture, although in practice many clinicians aim for a count of above 50 x 10^9/litre. An international normalized ratio of below 1.5 is also considered safe for lumbar puncture (Harrop-Griffiths et al, 2013).

Neither the Association of British Neurologists, nor the UK Joint Specialist Society on the diagnosis and management of acute meningitis, recommend routine coagulopathy screening before lumbar puncture. However, they do recommend it for those with a personal or family history of bleeding disorders, or those on anticoagulants (McGill et al, 2016; Dodd et al, 2018).

If a lumbar puncture needs to be performed urgently when a patient is on anticoagulant medication, then advice should be sought from a haematologist regarding reversal.

Considerations when performing lumbar puncture

Consent

Informed consent is an important step before all medical procedures. The purpose of performing the lumbar puncture and the risks should be discussed with the patient. Ideally written consent should be obtained. *Table 2* outlines risks and associated incidence (Cook et al, 2009).

Although lumbar puncture is a safe procedure, the following complications should be discussed:

- Postdural puncture headache – caused by CSF leakage
- Infection – leading to meningitis, or vertebral canal or epidural abscess
- Bleeding – leading to vertebral canal or epidural haematoma
- Nerve injury – as a result of direct trauma to nerves, or as a consequence of infection or bleeding.

The incidence of some of these complications is difficult to assess because they are so rare. The complication rates of spinal and epidural anaesthesia were examined in the NAP3 study, which may be extrapolated when consenting for lumbar puncture (Cook et al, 2009). However, medication is injected intrathecally for spinal anaesthesia, therefore it might be expected that the risks of nerve injury and infection would be higher in this cohort of patients than for those having lumbar puncture for CSF sampling.

Postdural puncture headache and needle choice

Postdural puncture headache is the most common complication following lumbar puncture and is caused by leakage of CSF through a breach in the dura. It is characterized by a frontal headache that is worse sitting up and better when lying down, typically presenting within the first 3 days post-procedure. Associated symptoms include nausea, tinnitus, vertigo and photophobia (Obstetric Anaesthetists' Association, 2014). It ranges in severity, but can be debilitating. The incidence of postdural puncture headache is quoted as up to 35% (Lavi et al, 2006). Patients in the 18–35-year-old age group are more at risk (Leibold et al, 1993).

There are two factors in needle choice that influence the incidence of developing a postdural puncture headache:

- Gauge of the needle – a smaller gauge needle leaves a smaller hole in the dura and decreases the likelihood of developing a postdural puncture headache
- Type of needle – an atraumatic 'pencil point' (rather than cutting) needle decreases the incidence.

A conventional Quinke 'cutting' spinal needle has a sharp tip and an open end (*Figure 1*). Atraumatic spinal needles have a pencil point-shaped tip with a side port hole. When a pencil point needle punctures the dura it separates the fibres rather than cutting them, leaving a smaller hole meaning that CSF is less likely to leak out. The likelihood of developing a postdural puncture headache is less with an atraumatic spinal needle (Rochwerg et al, 2018). Consequently, the use of atraumatic spinal needles for lumbar puncture is strongly recommended (Nath et al, 2018; Rochwerg et al, 2018).

Lumbar puncture forms part of the workup for patients presenting with headache. After a lumbar puncture, differentiating between the presenting headache and a postdural puncture headache may be challenging and lead to under-diagnosis.

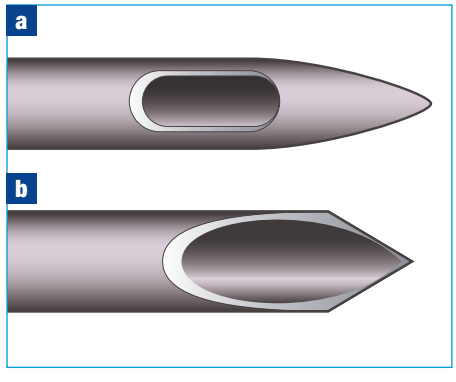
Most cases of postdural puncture headache will resolve spontaneously (Obstetric Anaesthetists' Association, 2014). For those that do not, simple analgesia and bed rest is normally adequate therapy. Although there is no evidence that fluid therapy improves outcome, patients are normally advised to remain well hydrated. In those cases that do not resolve, epidural blood patch can be a definitive treatment. However, this requires specialist anaesthetic input, is not risk free, and in some individuals multiple blood patches are required (van Kooten et al, 2008).

Table 2. Consenting for a lumbar puncture: what to tell patients

Risk		Likelihood*
Postdural puncture headache		Common
Nerve damage†	Temporary	Rare
	Permanent	Very rare
Infection (leading to meningitis, or vertebral canal or epidural abscess)		Very rare
Bleeding (leading to vertebral canal or epidural haematoma)		Very rare

**Common <1/10; uncommon <1/100; rare <1/1000; very rare <1/10 000. 'Nerve damage' is defined as an area of numbness, weakness or pain. †Temporary = symptoms that lasting <6 months; permanent = symptoms lasting >6 months*

Figure 1. a. Atraumatic or 'pencil point' needle *vs* (b) conventional or 'cutting' needle. The incidence of postdural puncture headache is lower when an atraumatic needle is used.



Caffeine has been shown to be successful in treating postdural puncture headache in some small trials (Basurto Ona et al, 2015). Desmopressin and sumatriptan have been trialled, but current evidence does not support their use.

Preparation and asepsis

Ensure there are no contraindications to lumbar puncture, reviewing any relevant investigations such as neuroimaging and bloods.

Ensure all the equipment you need is available (*Table 3*).

An aseptic technique for lumbar puncture is important to avoid infection as a complication. However, there does not appear to be a consensus about what constitutes aseptic technique when performing a lumbar puncture (Malhotra and Kelly, 2012).

The Association of Anaesthetists of Great Britain and Ireland advise 'full asepsis' for administering intrathecal medications. This includes surgical scrubbing, the donning of a hat, mask, gloves and gown and the use of sterile drapes. However, no other specialist committees, colleges or regulatory bodies recommend such stringent asepsis precautions, and it is common for routine lumbar punctures to be performed on the ward by practitioners using only sterile gloves. It is therefore the opinion of the authors that, as a minimum, a face mask should be worn alongside surgical hand scrubbing, wearing sterile gloves, using sterile drapes, and using antibacterial solution to clean the skin overlying the lumbar puncture site. However, if time allowed, full asepsis, as advocated by the Association of Anaesthetists of Great Britain and Ireland et al (2014), would seem advisable.

Table 3. Checklist of required items before performing a lumbar puncture

Patient consent
Assistant to help position patient and hand over equipment
Non sterile: hat and mask. Sterile: pack, gown, gloves, drape
Solution to clean skin (ideally chlorhexidine 0.5%)
Lidocaine 1% and drawing up needle
Syringe and narrow bore needle to administer lidocaine
Spinal needle (atraumatic, if available, e.g. Whitacre)
Manometer with 3-way tap (if opening pressure needed)
Bottles for CSF (at least 3 x sterile sample bottles; 1 x fluoride 'grey top' blood bottle for glucose)
Dressing

Anatomical landmarks

The level at which a lumbar puncture is performed relates to the anatomy of the spinal cord. The spinal cord ends at approximately L1 in adults, so performing a lumbar puncture below this level is considered to be safer as there is a lower risk of direct damage to the spinal cord. Typically, lumbar punctures are performed at the L3/4 or L4/5 interspace (*Figure 2*).

The location of the L4 vertebral body can be approximated using anatomical landmarks in order to guide your level of insertion for lumbar puncture (ideally with the patient sitting). First identify each iliac crest by palpation. A line interconnecting the top of each iliac crest (Tuffier's line) approximates to the spinous process of L4, with the spaces above and below this landmark denoting the L3/4 and L4/5 interspaces.

The approximate depth to the dura from the skin in an average-sized patient is 4.5–5.5 cm.

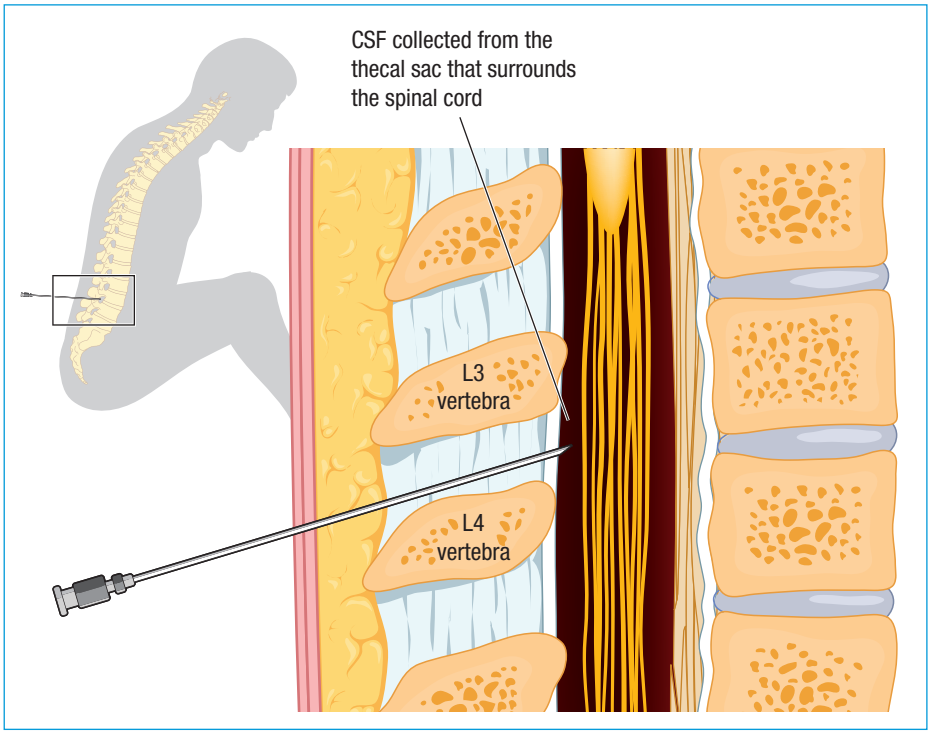
Positioning

Positioning is key to success. Not only are you more likely to successfully secure CSF samples, but needle attempts are reduced, and therefore patient comfort is improved.

Lumbar puncture can be performed with the patient sitting or in the lateral position. Although anatomical landmarks can be easier to locate with the patient sitting, the effect of gravity increases CSF pressure at the needle insertion point meaning the CSF pressure cannot be accurately measured with the patient in this position.

Increasing the space between spinous processes will significantly increase the likelihood of success. To achieve this, the patient needs to be curled up as much as possible. This can be achieved by ensuring the patient's knees are brought up towards the chest, with the hips and knees maximally flexed, and the chin on the patient's chest. It is important to check the alignment of the spine before starting, especially in the lateral position. Giving the patient a pillow to hug can be useful to help the patient curl up, particularly if he/she is in the sitting position.

Figure 2. Method for performing lumbar puncture, showing the level of insertion and the spinal cord transitioning to the cauda equina.



TOP TIPS

- Positioning is really important: it can turn a difficult lumbar puncture into an easy one.
- Spend some time setting everything up, you do not want to realize you have forgotten something after you have scrubbed up.
- Think about sitting the patient up if you are struggling.
- If unsure about contraindications, check the guidelines.

Cleaning the skin

The skin overlying the needle insertion site should be cleaned with an antiseptic solution, usually 0.5% chlorhexidine in alcohol. There has been some concern about the association between use of chlorhexidine before lumbar puncture and arachnoiditis leading to severe neurological sequelae (Scott et al, 2009). The evidence for this is limited, but in recent years the trend has moved from using a higher strength solution (2% chlorhexidine) to 0.5% chlorhexidine, which offers a safer balance between adequate skin preparation and a lower risk of neurological pathology. It is essential to allow the chlorhexidine to dry fully before instrumenting the skin and to keep it well away from the other lumbar puncture kit to avoid contamination and potential introduction into the CNS.

Which samples to send

For suspected meningitis the following samples are recommended: CSF microscopy, culture and sensitivity, meningococcal and pneumococcal polymerase chain reaction, CSF protein, lactate and glucose. It is important to remember to send appropriate paired serum samples so that CSF values can be compared. These may include full blood count, liver function tests, glucose, lactate and blood cultures (McGill et al, 2016).

Other CSF investigations may include virology for suspected encephalitis, xanthochromia to investigate subarachnoid haemorrhage (NB must be sent in opaque bottle or bottle kept in dark), cytology to look for malignant disease, oligoclonal bands to investigate inflammatory disease, e.g. multiple sclerosis. *Table 4* gives a step by step guide to performing a lumbar puncture.

Table 4. Lumbar puncture: step-by-step guide

Consent patient	
Position patient, remember that good position can be the key to turning a 'difficult lumbar puncture' into a more straightforward procedure	
Find anatomical landmarks and decide on position for insertion of needle; usually at L3/4 or L4/5. You may wish to mark the needle entry point (gently pressing the blunt hub of a needle against the skin can be a useful marker)	
Get all equipment ready. Ideally do not open it until after skin cleaning with chlorhexidine. Make sure you have all the sample bottles you need	
Clean patient's back with 0.5% chlorhexidine (in 70% alcohol) and allow to dry. Do not re-touch this area until you are sterile	
Set up your sterile field on a dedicated trolley, then open your sterile equipment onto it	
Put on hat (if using) and mask, then scrub hands before putting on sterile gown (if using) and sterile gloves	
Draw up lidocaine (you will need your assistant to open and hold this while you draw it up), then replace the drawing up needle with a small gauge needle for administration	
Apply sterile drape over patient's back	
Once draped, palpate patient's back again to identify the spinous process of L4 and identify interspinous space. Aim to insert the needle just superior to the spinous process you have identified – if you come across bone with your needle it is likely to be the top of the spinous process (at the inferior margin of the space). Manoeuvring the needle cephalad will direct you towards the space	
Inject local anaesthetic to the skin and subcutaneous tissues around the intended area of lumbar puncture. Be sure to raise a good bleb of local anaesthetic to anaesthetise the skin, as initial skin puncture with the introducer is usually the most uncomfortable part of the procedure	
Insert the introducer, initially angling slightly cephalad and towards the umbilicus. Make sure your introducer is perpendicular to the spine, especially when the patient is in the lateral position, as it is easy to aim off-centre	
Insert the spinal needle through the introducer. Usually, while the needle is being passed through ligament, it feels quite firm, as if you are pushing the needle through a block of hard cheese	
Once the dura is punctured, you may feel a slight loss of resistance or a 'pop'	
Withdraw the stylet from the needle and see if CSF flows. It is worth waiting a few seconds if using narrow bore spinal needles. If CSF does not appear consider the following:	Advancing the needle slightly further
	Replacing the stylet, withdrawing the needle and re-angling
	If the patient is lying on his/her side, sit him/her up and repeat the lumbar puncture
	Getting help from a senior
If the patient complains of pain during the procedure it is usually because the needle is not in the true midline. Asking the patient which side the discomfort is felt can help direct needle repositioning	
Once CSF is flowing, attach the manometer (if opening pressure measurement is needed), and wait for it to fill and equilibrate. This is the opening pressure	
Next fill the sample bottles – 10–20 drops per sample is usually enough	
Reinsert the stylet and remove the introducer and needle together	
Apply dressing	
Ensure you label the samples and call the pathology lab if you are sending an urgent sample	

Interpreting the results

Correct interpretation of results can help guide diagnosis and treatment. *Table 5* summarizes CSF changes seen in certain CNS conditions.

Conclusions

Lumbar puncture is a routine but often vitally important investigation. It can also be therapeutic or a route for medication administration. It is essential to check for contraindications before performing a lumbar puncture and to appropriately consent the patient. It is not a risk-free procedure, with the commonest complication being headache. Measures can be taken to reduce complications and improve comfort, including using effective technique and careful needle selection. Many tests may be performed from a lumbar puncture, and it is essential to ensure all necessary samples are taken and sent in the correct manner to optimize diagnostic yield. **BJHM**

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Association of Anaesthetists of Great Britain and Ireland, Obstetric Anaesthetists' Association; Regional Anaesthesia UK; Association of Paediatric Anaesthetists of Great Britain and Ireland, Campbell JP, Plaat F, Checketts MR et al. Safety guideline: skin antisepsis for central neuraxial blockade. Anaesthesia. 2014 Nov;69(11):1279–86. https://doi.org/10.1111/anae.12844

Basurto Ona X, Osorio D, Bonfill Cosp X. Drug therapy for treating post-dural puncture headache. Cochrane Database Syst Rev. 2015 Jul 15;(7):CD007887. https://doi.org/10.1002/14651858.CD007887.pub3

Cook TM, Counsell D, Wildsmith JAW; Royal College of Anaesthetists Third National Audit Project. Major complications of central neuraxial block: report on the Third National Audit Project of the Royal College of Anaesthetists. Br J Anaesth. 2009 Feb;102(2):179–190. https://doi.org/10.1093/bja/aen360

Dodd KC, Emsley HCA, Desborough MJR, Chhetri SK. Periprocedural antithrombotic management for lumbar puncture: Association of British Neurologists clinical guideline. Pract Neurol. 2018 Aug 28. https://doi.org/10.1136/practneurol-2017-001820

Harrop-Griffiths W, Cook T, Gill H et al; Working Party; Association of Anaesthetists of Great Britain & Ireland; Obstetric Anaesthetists' Association; Regional Anaesthesia UK. Regional anaesthesia and patients with abnormalities of coagulation. Anaesthesia. 2013 Sep;68(9):966–972. https://doi.org/10.1111/anae.12359

Lavi R, Yernitzky D, Rowe JM, Weissman A, Segal D, Avivi I. Standard vs atraumatic Whitacre needle for diagnostic lumbar puncture: A randomized trial. Neurology. 2006 Oct 24;67(8):1492–1494. https://doi.org/10.1212/01.wnl.0000240054.40274.8a

Leibold RA, Yealy DM, Coppola M, Cantees KK. Post-dural-puncture headache: Characteristics, management, and prevention. Ann Emerg Med. 1993 Dec;22(12):1863–1870. https://doi.org/10.1016/S0196-0644(05)80416-0

Malhotra R, Kelly S. A survey of aseptic technique when performing lumbar puncture: a comparison of medical and anaesthetic trainees. BJMP. 2012;5(1):503.

Mark DG, Sonne DC, Jun P, Schwartz DT, Kene MV, Vinson DR, Ballard DW. False-negative interpretations of cranial computed tomography in aneurysmal subarachnoid hemorrhage. Acad Emerg Med. 2016 May;23(5):591–598. https://doi.org/10.1111/acem.12941

McGill F, Heyderman RS, Michael BD et al. The UK joint specialist societies guideline on the diagnosis and management of acute meningitis and meningococcal sepsis in immunocompetent adults. J Infect. 2016 Apr;72(4):405–438. https://doi.org/10.1016/j.jinf.2016.01.007

Nath S, Koziarz A, Badhiwala JH et al. Atraumatic versus conventional lumbar puncture needles: a systematic review and meta-analysis. Lancet. 2018 Mar;391(10126):1197–1204. https://doi.org/10.1016/S0140-6736(17)32451-0

Obstetric Anaesthetists' Association. 2014. Guideline on Post Dural Puncture Headache. (accessed 20 October 2018) https://www.oaa-anaes.ac.uk/assets/_managed/cms/files/Clinical%20Guidelines/PDPH_Stevenage_2014.pdf

Rochwerg B, Almenawer SA, Siemieniuk RAC et al. Atraumatic (pencil-point) versus conventional needles for lumbar puncture: a clinical practice guideline. BMJ. 2018 May 22;361:k1920. https://doi.org/10.1136/bmj.k1920

Scott M, Stones J, Payne N. Antiseptic solutions for central neuraxial blockade: which concentration of chlorhexidine in alcohol should we use? Br J Anaesth. 2009 Sep;103(3):456–457, author reply 456–457. https://doi.org/10.1093/bja/aep214

Vandermeulen EP, Aken HV, Vermylen J. Anticoagulants and spinal-epidural anesthesia. Anesth Analg. 1994 Dec;79(6):1165–1177. https://doi.org/10.1213/00000539-199412000-00024

van Kooten F, Oedit R, Bakker SLM, Dippel DWJ. Epidural blood patch in post dural puncture headache: a randomised, observer-blind, controlled clinical trial. J Neurol Neurosurg Psychiatry. 2008 May 01;79(5):553–558. https://doi.org/10.1136/jnnp.2007.122879

van Veen JJ, Nokes TJ, Makris M. The risk of spinal haematoma following neuraxial anaesthesia or lumbar puncture in thrombocytopenic individuals. Br J Haematol. 2010 Jan;148(1):15–25. https://doi.org/10.1111/j.1365-2141.2009.07899.x

KEY POINTS

- Lumbar puncture is a useful investigative procedure, especially for CNS infection.
- Lumbar puncture is a relatively safe procedure. Knowing the potential complications is important for consenting patients appropriately.
- Headache is the most common complication.
- Contraindications include certain anticoagulant and antiplatelet medications, raised intracranial pressure and overlying infection.
- Using anatomical landmarks and correctly positioning the patient can increase the likelihood of successful lumbar puncture.
- Postdural puncture headache can be reduced by using an atraumatic needle and a smaller gauge needle.

Table 5. CSF changes in different pathologies

	Normal values	Bacterial meningitis	Viral meningitis	Fungal meningitis	Tuberculosis	Subarachnoid haemorrhage
Appearance	Clear	Cloudy	Clear	Clear or cloudy	Clear or cloudy	Clear or bloody
Opening pressure (cmH_2O)	10–20	Elevated	Normal or elevated	Elevated	Elevated	Elevated
White cell count (cells/µl)	0–5	>100 (mostly polymorphonuclear)	10–1000 (mostly lymphocytes)	10–500	50–500	1 per 1000 red blood cells
Glucose (% of serum value)	>60%	Low (<40%)	Normal	Low	Low	Normal
Protein (mg/dl)	<45	Elevated	Elevated	Elevated	Elevated	Elevated
Additional tests		CSF Gram stain, culture +/- polymerase chain reaction	Polymerase chain reaction	CSF India ink +/- cryptococcal antigen	CSF stain, culture for acid fast bacilli +/- polymerase chain reaction	Photospectrometry for xanthochromia

adapted from http://www.oxfordmedicaleducation.com/clinical-skills/procedures/csf-interpretation/